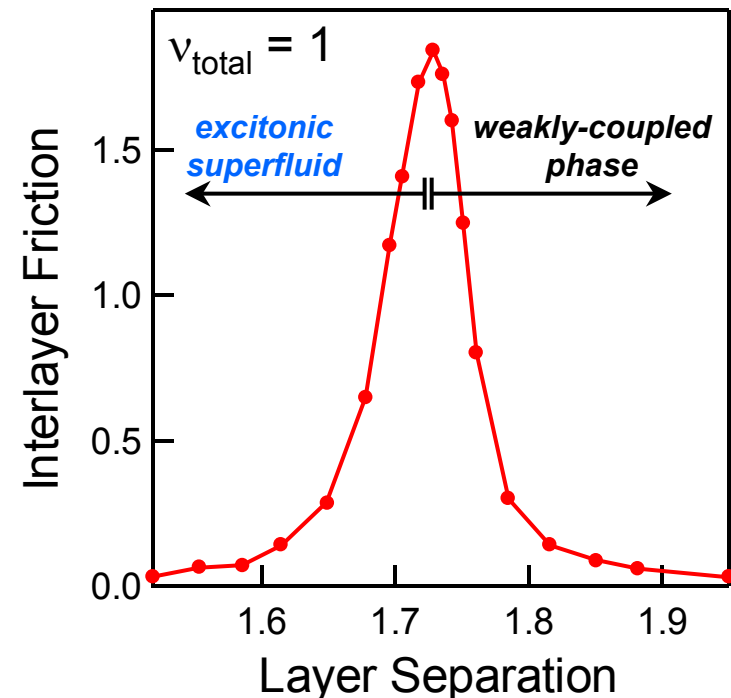
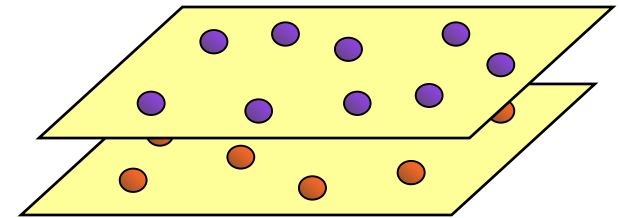


Interlayer Friction in an Excitonic Superfluid

J.P. Eisenstein Caltech DMR 0070890

Artificial quantum structures engineered out of technologically important semiconductor materials have produced a bonanza of important new physics. Our recent work has centered on a particularly interesting example: the condensation of an “excitonic superfluid” in a double layer electron gas. When two layers of electrons are close together, interlayer interactions (plus a large magnetic field) can lead to the formation of a new phase of matter in which an electron in one layer is bound to a “hole” in the electron gas in the other layer. If the layers are too far apart this does not occur. How this transition comes about is very poorly understood. In order to study this question, we measure the “friction” that one layer exerts upon the other. Surprisingly, the friction becomes quite large just when the layer separation is near the critical value. This unpredicted result may reflect the so-called critical fluctuations common to many phase transitions or it may be due to phase separation. Either way, these data will improve our understanding of how excitonic condensation occurs in bilayer systems.

double layer 2D electron gas



Interlayer Friction in an Excitonic Superfluid

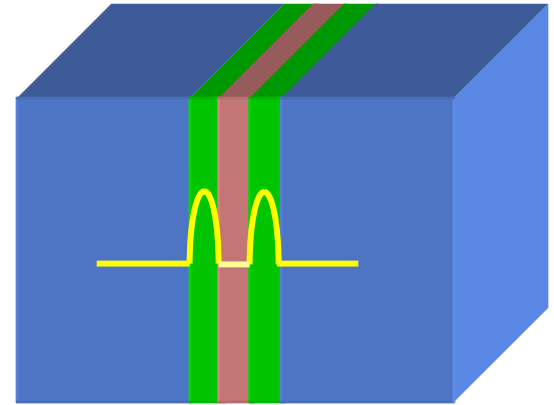
J.P. Eisenstein Caltech DMR 0070890

Graduate Students: Melinda J. Kellogg and Ian B. Spielman - Caltech

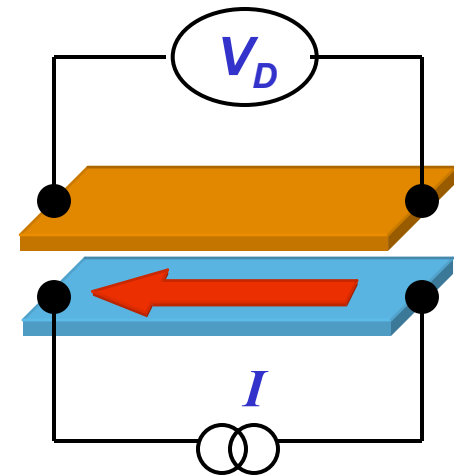
Collaborators: Loren N. Pfeiffer and Kenneth W. West, Bell Laboratories, Lucent Technologies

Related Manuscripts: “Coulomb Drag Near the Excitonic Phase Boundary in Double Layer Two Dimensional Electron Systems”, *in preparation*.

“Observation of Quantized Hall Drag in a Strongly Correlated Double Layer Bilayer Electron System”, *Physical Review Letters*, **88**, 126804 (2002).



Schematic of a GaAs/AlGaAs double quantum well heterostructure.



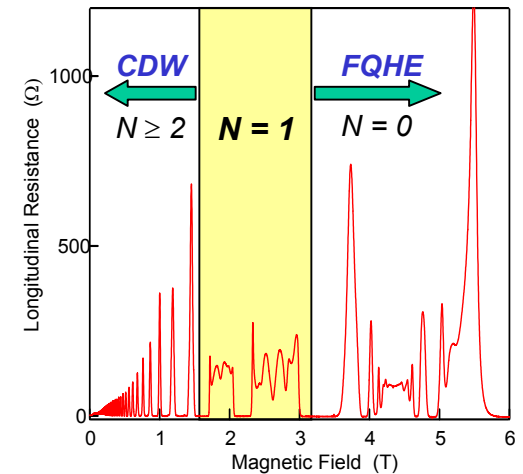
Configuration for measuring friction between two 2D electron layers. Without interlayer friction $V_D = 0$.

New Insulators in 2D Electron Systems

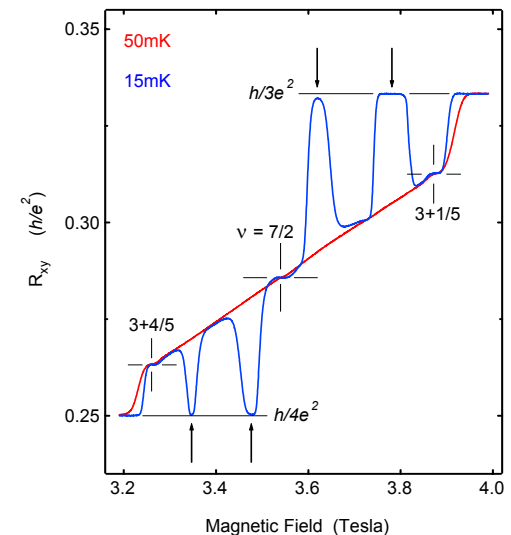
J.P. Eisenstein Caltech DMR 0070890

Two-dimensional electron systems are justly famous for their display of the *fractional quantum Hall effect*. The FQHE, which signals the development of exotic electron quantum fluids, occurs when an applied magnetic field is large enough to force all electrons into the lowest ($N=0$) quantized cyclotron orbit (Landau level). More recently, with NSF funding, we discovered a new class of *charge density wave (CDW)*, or *liquid crystalline*, states when three or more Landau levels ($N \geq 2$) are occupied.

We have now closed the loop with an important discovery in the first excited, or $N=1$, Landau level. This level, home to the famously puzzling even-denominator FQHE state, has been found to support **several new insulating phases** which have not, to our knowledge, been predicted by any theory. These new states, which are manifested by a peculiar *re-entrant* integer Hall quantization appear only at ultra-low temperatures and in the world's best samples. They may represent crystals comprised of multi-electron bubbles or be more closely related to quantum Wigner solids. Our investigation of them is just beginning.



Magneto-resistance of 2D electron gas. Shaded region is $N=1$ Landau level.



Hall resistance of 2D electron gas in $N=1$ Landau level. Arrows indicate re-entrant insulating states at 15mK.

New Insulators in 2D Electron Systems

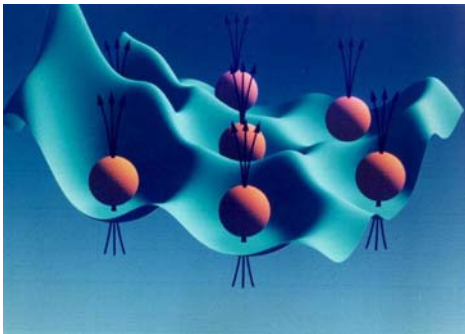
J.P. Eisenstein Caltech

DMR 0070890

Graduate Student: Kenneth B. Cooper, Caltech

Collaborators: Loren N. Pfeiffer and Kenneth W. West, Bell Laboratories, Lucent Technologies

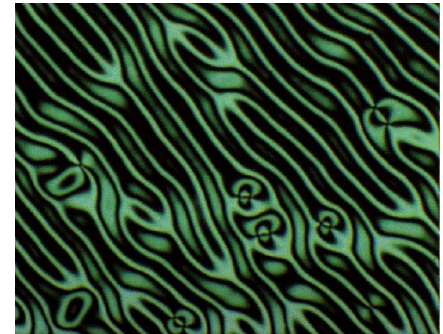
Publication: “Insulating and Fractional Quantum Hall States in the First Excited Landau Level”, *Phys. Rev. Lett.* **88**, 076801 (2002).



Cartoon depiction of $\nu = 1/3$ FQHE state in $N=0$ Landau level.

$N = 1$ Landau level

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Cartoon depiction of liquid crystal state near half-filling of $N \geq 2$ Landau levels.